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Zeboid cow milk: physicochemical quality indicators

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Abstract:
Introduction. A herd of zeboid cattle was created by the Snegiri Scientific and Experimental Farm (Moscow region, Russia) as a result of long-term selection and crossbreeding zebu (*Bos indicus* L.) with cattle (*Bos taurus* L.). These hybrid cows have good physiological parameters, high resistance to diseases, and a significant adaptive potential. The quality of milk produced by zebu cows at different lactation and milking times has not been studied as well as their milking capacity. Therefore, we aimed to assess the variability of specific physicochemical indicators of milk produced by Snegiri's zeboid dairy herd.
Study objects and methods. The milk of 193 zeboid cows (6–12% of zebu blood) from the Snegiri Farm was analyzed by standard methods for quality indicators such as fat, nonfat milk solids, density, bound water, freezing point, protein, and lactose. Then, we determined how these indicators changed depending on the lactation number and the time of milking (morning/evening). Statistical analysis was applied to process the data.
Results and discussion. Such indicators as nonfat milk solids, density, bound water, freezing point, protein, and lactose of zeboid cow milk were consistent with the normal indicators for raw cow's milk. Only its fat content (4.39%) exceeded the norm. We found no correlation between the quality of milk and the number of lactations. However, the evening milk was more concentrated, with a significant increase in nonfat milk solids and density, as well as with a lower freezing point.
Conclusion. Zeboid cows, which can be bred in suboptimal conditions, produce milk suitable for dairy products since it has a high fat content regardless of lactation and milking time.

Keywords: Zeboid cattle, milk, quality indicators, fat, nonfat milk solids, density, freezing point

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INTRODUCTION

Crossbreeding zebu (*Bos indicus* L.) with cattle (*Bos taurus* L.) has produced hybrids that are well adapted to different natural and climatic conditions [1–3].

Although zebu cows are less prolific and have lower milk productivity than B. *taurus* breeds, they are better adapted to the environment and more resistant to a number of diseases. Zebu milk has a very high content of fat (5–6%) and protein (3.7–4.2%) [4]. Therefore, zebus are crossbred to produce hybrids with high-fat milk [5]. Like zebu, zeboid cows produce milk that is suitable for dairy products (butter, cheese, cream, cottage cheese, etc.). In addition, high-fat milk production is more cost-effective. Since one liter of 3.5% milk contains 30% less fat than one liter of 5% milk, farmers need more low-fat milk to produce, cool, store, transport, and process, which increases the cost of a dairy product [6].

This field has been so important that the Soviet Union established a special authority, the Council for

Breeding Zebu and Zeboid cattle, to provide guidance to its farms. As a result, Azerbaijan created a new breed of dairy cattle – the Azerbaijani Brown – by crossing zebu with the Brown Swiss and Brown Carpathian breeds. The new breed produced high-fat milk [7].

In 1967, Uzbekistan created the Bushuyev breed by crossing local zeboid cattle with the Dutch and Swiss bulls [5]. This breed was made up of 5 main lines, with the Mota TE-10 line producing the highest-fat milk (4.14%) [7]. The farms in the Vakhsh Valley, Tajikistan, crossed local zeboid cattle with the Brown Swiss to create the Tajik intra-breed type of the Swiss zeboid cattle. The cows of this type yielded 3000 kg of 4% fat milk [7]. Turkmenistan crossed zeboid cattle with the Red Steppe bulls to produce the Red zeboid cattle with a milk yield of 2000–2500 kg and a fat content of 3.8–4,0 % [5].

In 1956, the Snegiri Scientific and Experimental Farm of the Main Botanical Garden (Moscow region) became the first institution in the European part of Russia to experimentally cross the Azerbaijani zebu with the Black Pied breed [10]. The farm developed a unique breed of dairy zeboid cattle that was highly productive in a temperate climate zone with an average annual temperature of +4°C. Subsequently, new hybrids were created by crossing this unique breed with the Cuban and New Zealand zebu, as well as the Punjabi Sahiwal zebu. Then, the Snegiri Farm developed schemes to cross their bulls with other breeds, including the Black Pied, Jersey, Ayrshire, Kholmogory, Aulie-Ata, Simmental, Red Steppe, and Brown Latvian breeds. In 1999, they began to use Holstein bulls in crossbreeding to increase milk yield and improve the shape of the udder in hybrid cows [4].

The resulting crossbreeds were resistant to tuberculosis, brucellosis, leukemia, and other diseases. They inherited high fat and protein contents from zebu, had a good physiological capacity for milking, and increased milk yield in better feeding and maintenance conditions [11-13]. Among Snegiri's zeboid cattle, the Elite-Record class crossbreeds produce maximum milk yield (over 5000 kg per lactation), with an average fat content of 4.64% [4].

Although the factors of milk production by zeboid cows have been studied quite well, the milk's quality indicators deserve more attention [4, 10]. Therefore, we aimed to study individual physicochemical indicators of milk produced by Snegiri's zeboid cattle depending on the number of lactations and the time of milking (morning or evening).

STUDY OBJECTS AND METHODS

We studied the milk of 193 zeboid cows (6–12% of zebu blood) bred by the Snegiri Farm. In particular, we determined milk quality indicators such as fat, nonfat milk solids, density, bound water, freezing point, protein, and lactose. Then, we analyzed how they changed depending on the lactation number and milking time (morning/evening).

The above quality indicators were determined by the following methods: fat content by the Gerber method (volumetrically); nonfat milk solids – by calculation;

Table 1 Quality indicators ($M \pm \sigma$) of zeboid cattle milk against lactation number (Snegiri Farm, Moscow region)

Number of cows (n)	Quantitative and qualitative indicators of milk						
	Fat, %	Nonfat milk solids, %	Density, °A	Bound water, %	Freezing point, (-10^{-2}°C)	Protein, %	Lactose, %
	First lactation						
85	4.45 ± 0.760	8.25 ± 0.338	26.51 ± 1.367	3.13 ± 0.899	54.18 ± 2.036	3.08 ± 1.229	4.69 ± 0.185
	Second lactation						
15	4.34 ± 0.856	8.39 ± 0.301	26.14 ± 1.433	2.20 ± 0.148	54.99 ± 1.835	2.99 ± 0.110	4.77 ± 0.167
	Third lactation						
26	4.45 ± 0.931	8.34 ± 0.324	26.87 ± 1.405	2.51 ± 0.621	54.68 ± 1.979	2.98 ± 0.122	4.74 ± 0.176
	Fourth lactation						
32	4.54 ± 1.205	8.09 ± 0.783	26.32 ± 1.877	3.13 ± 0.119	54.01 ± 2.242	2.94 ± 0.136	4.60 ± 0.444
	Fifth lactation						
13	4.46 ± 0.707	8.17 ± 0.467	26.17 ± 1.593	3.93 ± 0.517	53.58 ± 2.822	2.92 ± 0.169	4.64 ± 0.253
	Sixth lactation						
7	4.01 ± 1.037	8.29 ± 0.299	27.03 ± 1.203	2.82 ± 0.513	54.38 ± 1.784	2.95 ± 0.113	4.72 ± 0.164
	Seventh lactation						
6	3.83 ± 0.955	8.25 ± 0.264	27.03 ± 1.006	2.98 ± 0.414	54.28 ± 1.510	2.92 ± 0.104	4.64 ± 0.163
	Eighth lactation						
9	3.77 ± 1.087*	8.30 ± 0.278	27.28 ± 1.927	2.51 ± 0.379	54.62 ± 1.759	2.96 ± 0.094	4.73 ± 0.163
	Mean values for all lactations						
193	4.39 ± 0.911	8.25 ± 0.445	26.62 ± 1.510	3.08 ± 0.929	54.27 ± 2.069	3.01 ± 0.821	4.69 ± 0.249

Note: * $P < 0.05$

density – on a lactodensimeter; bound water – in a RD-8 dryer (Funke Gerber); freezing point – cryoscopically; protein content – by the Kjeldahl method; and lactose content – by the refractometric method.

The standard deviation (σ) indicated the variability of the mean value (*M*). Primary data grouping and biometric calculations were performed in Excel Microsoft and STATISTICA.

Randomly selected data were statistically analyzed by the Student's t-test, with the normality of distribution preliminarily determined by the Kolmogorov-Smirnov and Shapiro-Wilk tests. The nonparametric Mann-Whitney U-test was used in case the populations from which the data were selected for comparison were not distributed normally.

RESULTS AND DISCUSSION

The analysis of milk quality against lactation number (Table 1) showed that only the eighth lactation cows had a significant decrease in milk fat compared with the first lactation cows (3.77 and 4.45%, respectively) ($P < 0.05$). We noticed that this indicator became more variable with the age of the cows (σ = 0.760 for the 1st lactation and σ = 1.087 for the 8th lactation).

As we can see in Table 1, the mean fat content (4.39%) in the zeboid cattle milk was significantly higher than the standard content (3.4%) in Russia. The mean protein content (3.01%) was consistent with the Russian norm (3%). The freezing point (–0.543°C) of the milk samples was in line with the Russian Standard for raw cow's milk (R 52054-2003) and the European Standard for the extra grade milk [14]. The contents of bound (adsorption-bound) water (3.08%), lactose (4.69%), and nonfat milk solids (8.25%) were consistent with the standard indicators of cattle milk (2–3.5, 3.6–5.5, and > 8.2%, respectively) [15–17].

The mean density of the zeboid cattle milk (26.62°A) corresponded to the minimum norm for high-quality milk, 1.027 g/cm^3 (27°A). The low density of zebu milk is probably due to its high fat content, since studies show a decrease in density with an increase in fat [18].

Table 2. Quality indicators ($M \pm σ$) of zeboid cattle milk against lactation number and milking time (Snegiri Farm, Moscow region)

Milking time	Quantitative and qualitative indicators of milk						
	Fat, %	Nonfat milk solids, %	Density, °A	Bound water, %	Freezing point, (–10^{-2}°C)	Protein, %	Lactose, %
First lactation, n = 85							
Morning	5.09 ± 0.633	8.16 ± 0.380	26.10 ± 1.709	3.83 ± 0.577	53.57 ± 2.181	3.18 ± 2.475	4.64 ± 0.210
Evening	4.39 ± 0.974	8.35 ± 0.348**	26.92 ± 1.566**	2.42 ± 0.774*	54.80 ± 2.370	2.98 ± 0.129	4.74 ± 0.193**
Second lactation, n = 15							
Morning	4.58 ± 1.408	8.26 ± 0.271	26.42 ± 1.810	2.94 ± 0.580	54.15 ± 1.709	2.95 ± 0.096	4.70 ± 0.154
Evening	4.11 ± 0.861	8.51 ± 0.386*	27.86 ± 1.949*	1.46 ± 0.390	55.83 ± 2.409*	3.04 ± 0.138	4.84 ± 0.218*
Third lactation, n = 26							
Morning	4.67 ± 1.171	8.26 ± 0.327	26.34 ± 1.811	3.10 ± 0.960	54.17 ± 2.039	2.95 ± 0.118	4.69 ± 0.185
Evening	4.22 ± 1.394	8.42 ± 0.398	27.13 ± 1.936*	1.90 ± 0.825	55.23 ± 2.515	3.01 ± 0.148	4.70 ± 0.217
Fourth lactation, n = 32							
Morning	4.76 ± 1.433	8.16 ± 0.299	25.86 ± 1.770	3.90 ± 0.892	53.50 ± 1.759	2.92 ± 0.109	4.63 ± 0.169
Evening	4.31 ± 1.652	8.02 ± 1.546	26.78 ± 2.945	3.55 ± 0.953	54.52 ± 3.184	2.96 ± 0.180	4.56 ± 0.880
Fifth lactation, n = 13							
Morning	4.40 ± 0.448	8.13 ± 0.448	26.06 ± 1.548	3.98 ± 0.120	53.35 ± 2.850	2.90 ± 0.169	4.63 ± 0.242
Evening	4.52 ± 0.721	8.22 ± 0.527	26.28 ± 1.848	3.88 ± 0.004	55.81 ± 3.018	2.93 ± 0.197	4.67 ± 0.286
Sixth lactation, n = 7							
Morning	3.57 ± 0.701	8.24 ± 0.271	27.24 ± 0.866	2.94 ± 0.332	54.17 ± 1.614	2.93 ± 0.104	4.70 ± 0.146
Evening	4.45 ± 1.668	8.33 ± 0.390	26.81 ± 2.209	2.71 ± 0.212	54.59 ± 2.400	2.98 ± 0.143	4.74 ± 0.220
Seventh lactation, n = 6							
Morning	3.77 ± 1.242	8.27 ± 0.312	27.18 ± 1.612	2.87 ± 0.378	54.33 ± 1.881	2.90 ± 0.164	4.60 ± 0.340
Evening	3.90 ± 1.167	8.23 ± 0.303	26.88 ± 1.552	3.09 ± 0.067	54.22 ± 1.777	2.93 ± 0.114	4.68 ± 0.164
Eighth lactation, n = 9							
Morning	3.92 ± 0.897	8.26 ± 0.241	27.68 ± 2.130	2.68 ± 0.130	54.52 ± 1.543	2.94 ± 0.086	4.70 ± 0.137
Evening	3.63 ± 1.022	8.33 ± 0.451	27.54 ± 3.463	2.34 ± 0.886	54.71 ± 2.763	2.97 ± 0.147	4.75 ± 0.272
Mean values for all lactations, n = 193							
Morning	4.74 ± 1.853	8.19 ± 0.345	26.23 ± 1.706	3.57 ± 0.303	54.02 ± 3.970	3.04 ± 1.644	4.66 ± 0.198
Evening	4.29 ± 1.235	8.30 ± 0.724*	27.01 ± 2.075***	2.59 ± 0.162**	54.79 ± 2.583*	2.98 ± 0.147	4.72 ± 0.410

Note: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.00$

Then, we analyzed the milk quality indicators in relation to the milking time (morning/evening) of the zeboid cattle of different lactations (Table 2). We found that fat and protein contents in the morning and evening milk changed randomly within 3.57–5.09 and 2.90–3.18%, respectively. However, nonfat milk solids levels in the milk from the first and second lactations, as well as the mean value for all lactations, were significantly higher in the evening. The same trend was observed for the density of milk in the first three lactations and the mean values. The lactose content increased significantly by the evening milking only in the first and second lactations. However, the freezing point in the second lactation and the amount of bound water in the first and second lactations, as well as on average for all lactations, significantly decreased in the evening milking.

On the whole, the evening milk (Table 2) showed a significant decrease in bound water (from 3.57 to 2.59%) with a simultaneous increase in nonfat milk solids (from 8.19 to 8.23%) and a rise in milk density (from 26.23 to 27.01°A). The high density of the evening milk might be due to an increased amount of dissolved minerals, since the mean contents of protein and lactose did not change significantly in the entire herd. This was evidenced by the decrease in the freezing point of the evening milk from 54.02×10^{-2} to -54.79×10^{-2}°C.

The changes in the chemical and physical indicators of milk quality were primarily caused by the milk produced in the first three lactations. Besides, the number of cows in the first, second, and third lactations prevailed in the zeboid cattle herd.

Noteworthily, the crossing of zebu (*Bos indicus* L.) with cattle (*Bos taurus* L.) results in a pronounced relative heterosis, or the superiority of hybrids over the worst of the parental forms, in terms of milk quality, especially its fat content. Various authors have reported the following fat contents in the milk of the breeds that were used to create the zeboid cattle at the Snegiri Farm: 3.39 (Black Pied), 5.87 (Jersey), 4 (Ayrshire), 3.68 (Kholmogory), 3.85 (Aulie-Ata), 3.89 (Simmental), 3.82 (Red Steppe), 4.01 (Brown Latvian), and 3.6% (Holstein) [19–22]. The zebu (Azerbaijani, Cuban, New Zealand, and Sahiwal) produced 5.1–6.0% fat milk and the zeboid cattle in our study, 4.39% fat milk [7]. These data revealed an advantage of zeboid cattle over traditional breeds, since water metabolism in cows producing higher-fat milk puts less pressure on their body and is more economical in terms of energy and feed.

CONCLUSION

As a result of the study, we made the following conclusions.

1. The physicochemical indicators of zeboid cattle milk quality (fat, nonfat milk soilds, density, bound water, freezing point, protein, lactose) were consistent with the Russian standards for raw cow's milk, except for the fat content (4.39%), which significantly exceeded the norm.

2. The changes in the physicochemical indicators did not depend on the number of lactations. Only the eighth lactation cows showed a decrease in milk fat with age.

3. The evening milk was more concentrated, which manifested in an increased amount of NONFAT MILK SOLIDS, higher density, and a lower freezing point.

4. Given the high fat content, zeboid cattle milk is suitable to produce dairy products, regardless of lactation number and milking time. Besides, zeboid cattle can be bred effectively under suboptimal maintenance conditions.

CONTRIBUTION

The authors were equally involved in writing the manuscript and are equally responsible for plagiarism.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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